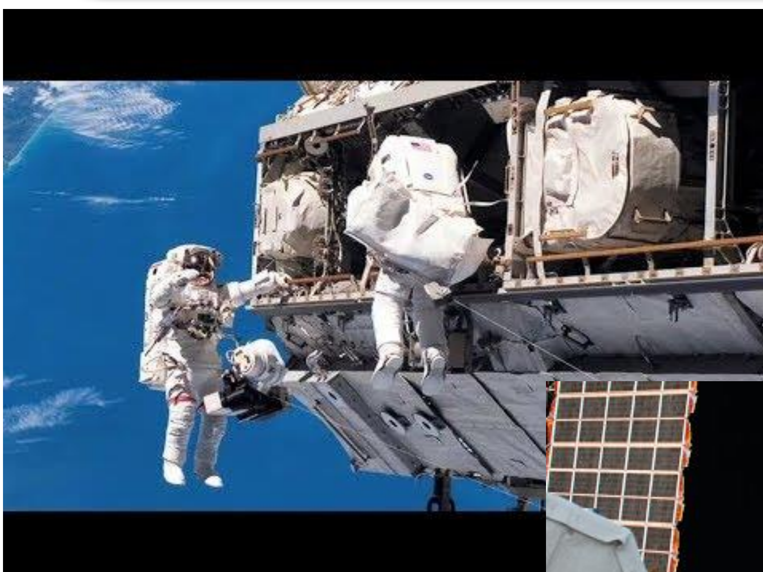
EVA Mishaps

Related Standards: **V2 3006, V2 4001, V2 7070, V2 7083, V2 9009, V2 9011-2, V2 9024, V2 9027, V2 11013, V2 11024, V2 11028, V2 11031, V2 11033-9**

Overview

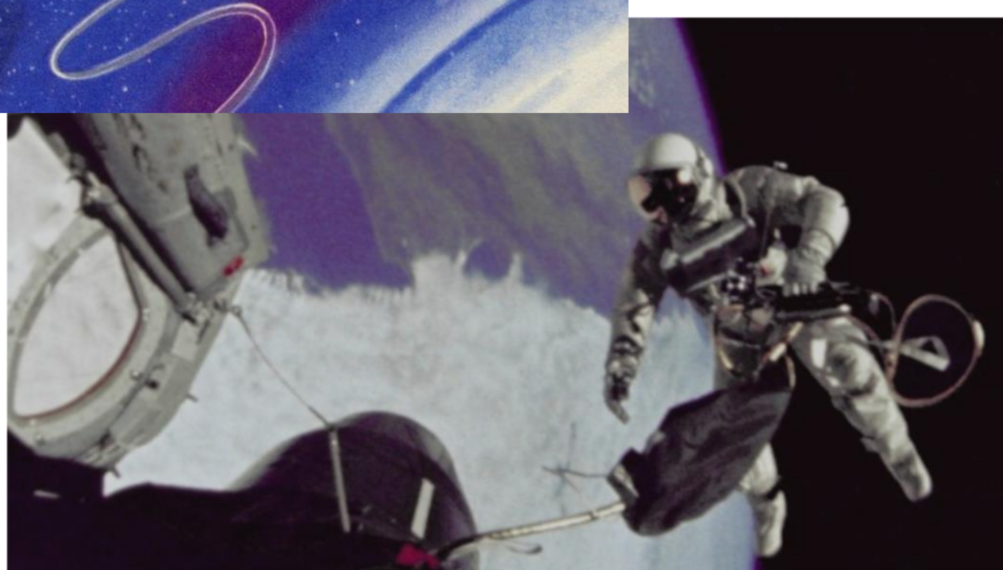
Executive Summary

Over the course of an EVA, the crew, equipment, and mission are all exposed to extraordinary risks. Tools can be damaged or lost, mission objectives can be failed, and astronauts can suffer a wide range of injuries, from minor cuts and bruises to thermal burns. The astronauts' lives depend on a long list of hardware and procedures operating as intended; if anything goes wrong the crew might not survive. EVA mishaps typically fall under three categories (or some combination thereof): hardware failures—where a tool or system doesn't perform its intended task, hardware damage, or missteps taken by the crew/mission control. Special considerations have to be undertaken so that all the equipment used by the crew can withstand the rigors of the EVA tasks, and that the operations required of the crew do not put them at unnecessary increased risk.



Risks

Due to the nature of the activities performed during EVAs, mishaps that occur over the course of an EVA pose a number of unique risks to the hardware, the crew, and the mission. Damage to the hardware might be as simple as a cracked casing or a lost wrench, or it could be as serious as a punctured suit that could lead to a fatal decompression. The crew experiences—or risks experiencing—injuries that range from minor to deadly. Missions have reported everything from bumps and contusions to more serious burns, exhaustion, and suffocation. A large number of mishaps also prevent mission objectives from being completed, either from hardware failures or crew injury. In extreme cases, the whole mission may have to be abandoned.



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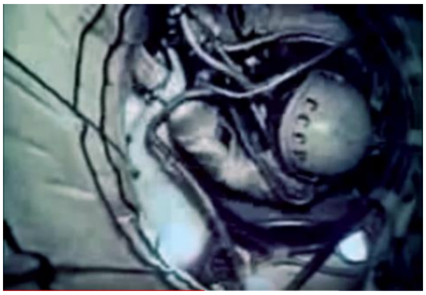
Hardware Failures

When hardware doesn't function as intended, an astronaut is forced to improvise which may increase the risk of injury or abandonment of the task.

Common Issues

- Elevated CO2 levels
- Helmet fogging
- Heating/cooling system failures
- Equipment coming unlatched

Example Events



Voskhod 2 (pictured): The cosmonaut's suit ballooned, impeding maneuverability and ingress. He eventually had to let out some air from his suit to gain enough flexibility to re-enter the crew capsule. In addition, the workload of the spacewalk exceeded the ability of the suit's cooling system to maintain temperature. By the end of the EVA the suit was filled to the knees with perspiration.

Relevant standards: V2 11024 Ability to Work in Suits, V2 11037 Suited Metabolic Rate Measurement, V2 11038 Suited Metabolic Rate Display

STS-136/137: In both missions, an astronaut experienced unsafe elevated CO2 levels during EVA when the EMU's CO2 scrubbers stopped working adequately. In both cases the EVAs were terminated early.

Relevant standards: V2 11034 Suited Atmospheric Data Recording, V2 11035 Suited Atmospheric Data Displaying, V2 11036 Suited Atmospheric Monitoring and Alerting, V2 11039 Nominal EVA Spacesuit Carbon Dioxide Levels

Skylab 2: Primary EVA heat exchangers suffered minor clogging during an EVA. A redesign was implemented, but there have been numerous issues with the heating & cooling systems that cause helmet fogging, and pose health risks to the crew.

Relevant standard: V2 11031 Suited Relative Humidity, V2 11035 Suited Atmospheric Data Displaying, V2 11036 Suited Atmospheric Monitoring and Alerting

STS-121: The latches on a SAFER became detached, putting an astronaut at an increased risk of drifting away from the shuttle. EVA tasks were postponed until the astronaut could be re-secured. The SAFER was later fixed using Kapton tape.

Relevant standard: V2 9027 Protection

Related Standards: **V2 3006, V2 4001, V2 7070, V2 7083, V2 9009, V2 9011-2, V2 9024, V2 9027, V2 11013, V2 11024, V2 11028, V2 11031, V2 11033-9**

Substances Present In Suit

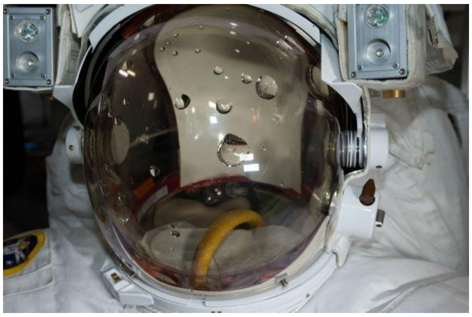
While this type of mishap is usually the result of a hardware failure, it happens frequently enough that it falls into its own subcategory. It often causes discomfort or irritation, and sufficient quantities of loose fluids in an astronaut's helmet puts them at risk of suffocation or drowning.

Common Issues

- Water
- Anti-fog agents
- Ammonia
- Urine

Example Events

ISS-36: An hour into EVA 3, a large amount of water had collected in astronaut Luca Parmitano's suit and helmet (pictured). He was unable to complete his to-do list, had impaired visibility, and ran the risk of suffocating. The EVA was terminated early and he was assisted back into the airlock. Water intrusion is a common occurrence among EVA mishaps.



Relevant standard: V2 9024 Fluid/Gas Release

STS-100: An astronaut experienced severe eye irritation during the spacewalk due to the anti-fog solution used to polish his spacesuit visor. A common cause of similar issues.

Relevant standard: V2 7083 Cleaning Materials

STS-130/ISS-24: Astronauts were exposed to ammonia from a leaking quick-disconnect fixture in the EMU.

Relevant standard: V2 9024 Fluid/Gas Release

STS-41-C: The urine containment system in the EMU failed. It caused discomfort to the astronaut, but the EVA was not terminated early.

Relevant standards: V2 9024 Fluid/Gas Release, V2 11013 Suited Body Waste Management—Provision, V2 11028 EVA Suit Urine Collection

Hardware Damage

Similar to hardware failure, hardware *damage* results in an inability to use equipment, and exposes the crew to increased risk. Damage to the suit is particularly concerning; in the past even minor punctures have resulted in early EVA terminations.

Common Issues
- Wear and tear
- Suit punctures

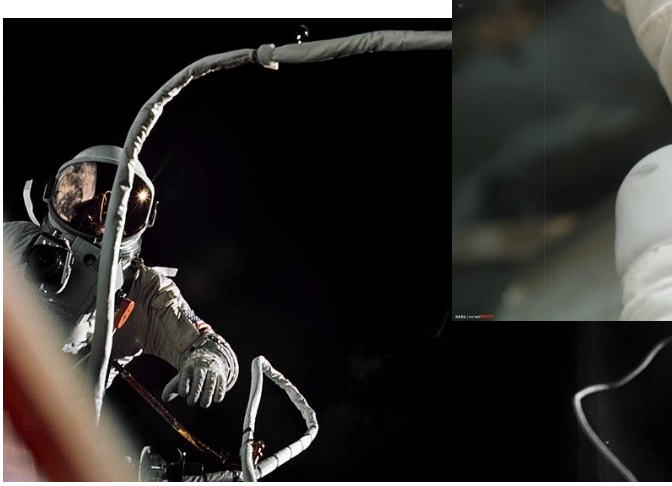
Example Events

Gemini 9 (pictured below-L): Over the course of his spacewalk, Gene Cernan's EVA suit became frayed and torn in spots along his back. As a result, he experienced painful heat exposure and suffered burns. Additionally, the workload required by the EVA overloaded the suit's cooling system; Cernan became overheated and exhausted, and his visor completely fogged up.

Relevant standards: V2 9027 Protection, V2 11031 Relative Suit Humidity, V2 11037 Suited Metabolic Rate Measurement, V2 11038 Suited Metabolic Rate Display

STS-37/118/125 (pictured below-R): At some point during each of these missions, an astronaut's glove was cut or punctured. These were likely caused by normal wear and tear, as well as handling equipment which may have had burrs or sharp edges.

Relevant standards: V2 9009 Sharp Corners and Edges—Fixed, V2 9011 Sharp Corners and Edges—Loose, V2 9012 Burrs, V2 9027 Protection



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Crew Actions/Ops

Even when all the hardware is intact and functioning correctly, actions taken by the crew or operational conditions of the mission can directly or indirectly increase the risk to an EVA. Mistakes are made by crew or support personnel, which can be exacerbated by external factors.

Common Issues

- Hardware secured or configured improperly
- Fatigue (pre-EVA & during EVA)
- Injuries from repeated actions
- Exposure to extreme conditions

Example Events

Salyut 6 PE-1: A cosmonaut's safety tether was not properly secured prior to his EVA. Although he was still connected to the Salyut via his umbilical, he was exposed to an increased risk of becoming detached and drifting away from the vehicle.

Relevant standard: V2 3006 Human-Centered Task Analysis

Gemini 11: EVA 1 was terminated early due to astronaut fatigue.

Relevant standard: V2 3006 Human-Centered Task Analysis, V2 7070 Sleep Accommodation

STS-37 (pictured below-L): Ground control recommended against EVAs on consecutive days due to concerns over crew fatigue and time constraints.

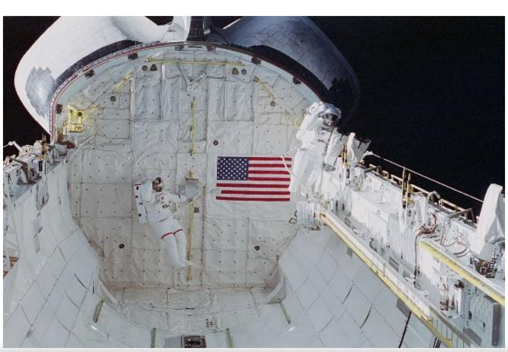
Relevant standard: V2 3006 Human-Centered Task Analysis, V2 7070 Sleep Accommodation

Apollo 15: The tight gloves, combined with the stress of repeating certain actions, resulted in minor hand injuries to the crew. A number of other missions have reported this phenomenon (below-R).

Relevant standard: V2 3006 Human-Centered Task Analysis, V2 4001 Data Sets

STS-57/63: Crew members reported feeling extremely cold in their EMUs. This was partly due to EVA operations taking place in complete shadow.

Relevant standard: V2 3006 Human-Centered Task Analysis, V2 11033 Suited Atmospheric Control



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Application Notes

While keeping in mind that tradeoffs always have to be balanced and 100% safety can't reasonably be achieved, there are steps that can be taken with regards to hardware design and operations structure that can mitigate risk and address common issues. Bear in mind that any recommendation has to be considered alongside other requirements.

Adding redundant features to hardware systems ensures that crew can continue using them even if one element fails or breaks. If there's a particular tool or piece of equipment that sees repeated use, it can be reinforced to withstand the extra stress. Lessons can be learned both from systems that fail regularly (are there common errors?) and resilient ones (why are they reliable?).

Mission operations can be designed to give crewmembers an advantage during EVAs. Taking care not to overwork them (before and during EVA) will reduce the risk of both human and hardware error. To that effect, other mission objectives must be taken into consideration when planning EVAs. Scheduling EVAs during favorable environmental conditions (low SPE activity, ample sunlight) helps astronauts work safely and effectively. Rigorous training can prepare crew for contingencies and reduce unfamiliar situations.

Reference Documents

NASA-STD 3001 Vol 2, Rev B
Significant Incidents & Close Calls in Human Spaceflight
Significant Incidents & Close Calls in Human Spaceflight: EVA Operations

Standards

V2 3006: Each human spaceflight program or project **shall** perform a task analysis to support hardware and operations design.

V2 4001: Each program **shall** identify or develop an anthropometry, biomechanics, aerobic capacity, and strength data set for the crewmember population to be accommodated in support of all requirements in section 4 of this NASA Technical Standard.

V2 7070: Each program **shall** identify or develop an anthropometry, biomechanics, aerobic capacity, and strength data set for the crewmember population to be accommodated in support of all requirements in section 4 of this NASA Technical Standard.

V2 7083: The system shall provide cleaning materials that are effective, safe for human use, and compatible with system water reclamation, air revitalization, and waste management systems.

V2 9009: Corners and edges of fixed and handheld equipment to which the bare skin of the crew could be exposed **shall** be rounded as specified in Table 16, Corners and Edges.

V2 9011: Corners and edges of loose equipment to which the crew could be exposed **shall** be rounded to radii no less than those given in Table 17, Loose Equipment Corners and Edges.

V2 9012: Exposed surfaces **shall** be free of burrs.

V2 9024: Hardware and equipment **shall** not release stored fluids or gases in a manner that causes injury to the crew.

V2 9027: Systems, hardware, and equipment **shall** be protected from and be capable of withstanding forces imposed intentionally or unintentionally by the crew.

Standards

V2 11013: Suits **shall** provide for management of urine, feces, menses, and vomitus of suited crewmembers.

V2 11024: Suits **shall** provide mobility, dexterity, and tactility to enable the crewmember to accomplish suited tasks within acceptable physical workload and fatigue limits while minimizing the risk of injury.

V2 11028: EVA suits **shall** be capable of collecting a total urine volume of V_u=0.5 +2.24t/24 L, where t is suited duration in hours.

V2 11031: For suited operations, the system **shall** limit RH to the levels in Table 22, Average Relative Humidity Exposure Limits for Suited Operations.

V2 11033: The suit **shall** allow the suited crewmembers and remote operators to adjust the suit thermal control system.

V2 11034: Systems **shall** automatically record suit pressure, ppO2, and ppC02.

V2 11035: Suits **shall** display suit pressure, ppO2, and ppCO2 data to the suited crew.

V2 11036: Suits **shall** monitor suit pressure, ppO2, and ppCO2 and alert the crew when they are outside safe limits.

V2 11037: The system **shall** measure or calculate metabolic rates of suited EVA crewmembers.

V2 11038: The system **shall** display metabolic data of suited EVA crewmembers to the crew.

V2 11039: The EVA spacesuit **shall** limit the inspired CO_2 partial pressure (P_ICO_2) in accordance with Table 23, EVA Spacesuit Inspired Partial Pressure of CO_2 (P_ICO_2) Limits.